THE GLASS INDUSTRY

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NEW OVENWARE PRODUCTION AT McKEE GLASS

For the manufacture of its well-known Glasbake ovenware the McKee Glass Company is now operating a new continuous tank with interesting features of design and control, together with a new muffle-type lehr.

Fig. 1. At the McKee Glass Co. the rebuilt No. 3 producer-fired tank for ovenware production is shown in this view which was made shortly after construction was completed.

In spite of its comparatively small size, the town of Jeannette, Pennsylvania, is really quite an industrial giant in the glass world. Located in the foothills of the Alleghenies some thirty miles east of Pittsburgh, it harbors no less than five glass manufacturing plants, and its products include practically every variety of pressed and blown ware, illuminating ware, sheet and safety glass. Of these five glass companies, the McKee Glass Company is most closely linked with the town and its history.

McKee Glass actually dates back to 1853 and to another locality; but it was not until 1887 that H. Sellers McKee decided to take advantage of the natural gas available in the hills east of Pittsburgh and moved his diminutive glass works here. The village that sprang up about the new plant was named in honor of Jennnette McKee, wife of H. Sellers, and the plant soon became one of the leading producers of tableware, chimneys, hospital and chemical ware, at one time manufacturing over one-fifth of the world's supply. Upon the retirement of H. Sellers McKee, shortly after the turn of the century, A. J. Smith became president of the company, coming from the National Glass Company in West Virginia to take over his new responsibility. Up to this time the pot furnaces and lehrs had been operated entirely upon natural gas, but the shrinking of the natural gas supply soon made it necessary for the new executive to seek a more economical fuel. Coal was available in abundance nearby and it was decided, therefore, to build a producer gas plant. The producers were installed in 1914 and, except in emergencies, the McKee factory has operated on producer gas ever since.

The first continuous tank at McKee Glass was built in 1920, replacing one of the pot furnaces, and this change to the more modern type of melting equipment continued during the ensuing twenty years until today practically all McKee glass is now melted in tanks. During this period of improvement and expansion the company has been under the leadership of M. A. Smith, son of A. J.,

Fig. 2. An interesting construction feature of the new No. 3 tank at McKee Glass Co. is the insulation of the regenerator chamber walls, shown in this view extending several feet above the factory floor.

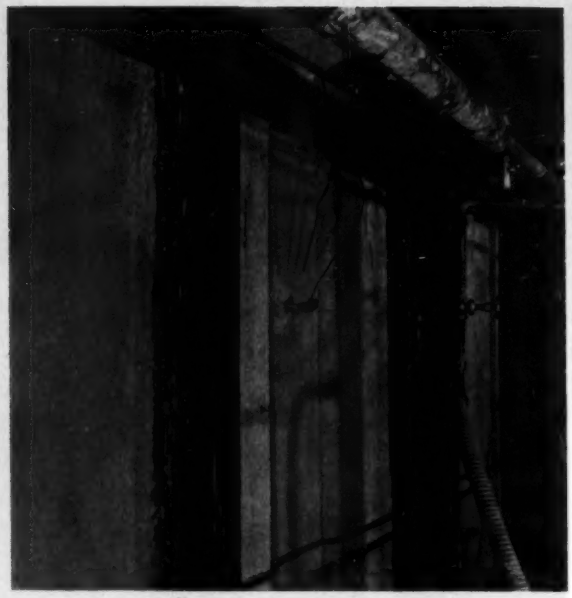


Fig. 3. The insulating cement covering of the regenerators in the basement is shown here, together with the thermocouple connection for the reversal signal system.

as president and general manager. The melting equipment now includes thirteen continuous tanks and two day tanks, the annealing being handled by fifteen muffle-type lehrs. With the advent of the continuous melting tank came also the use of semi-automatic and full-automatic forming machines for ware, and most of the McKee production today is machine-made.

Heat-resisting ware has come to be one of the leaders in the McKee line and includes Glasbake ovenware and industrial ware, chemical and laboratory glassware, kitchenware, lenses, reflectors and specialties. To improve the production speed and economy on heat-resisting ware, No. 3 tank was recently rebuilt throughout and the production unit was completed by the installation of an entirely new muffle-type lehr. The new unit was placed in operation in February, 1939, and has given excellent results in the way of ware quality and manufacturing economy.

The new McKee tank, parts of which can be seen in Fig. 1 and other accompanying illustrations, was designed by the Amsler-Morton Co. and has a melting capacity of 30 to 40 tons per day. It is regularly fired with producer gas, the fuel being supplied by the R. D. Wood producers that also serve other furnaces in the plant. The melting end is 16 ft. wide by 22 ft. long and has three ports on each side with accompanying gas and air checkers. Between the melting and refining ends is a bridge wall with a throat of rather unusual size, 10 in. high by 60 in. wide. The refining end is rectangular in shape, 18 ft. wide by 8 ft. long, the depth of the glass in this section being only 18 in. to provide thorough heat penetration throughout the glass in the pool. As is usual in recent Amsler-Morton designs, a cat-walk is supported on the backstays above the superstructure and extends clear around the furnace. This walk proves very convenient for inspection of the crown and for adjustment of tie-rods during the warming-up period.

A very interesting feature of the new tank is the use of insulating material on the walls of the regenerator chambers, the purpose of this covering being to decrease air infiltration as well as heat losses through the walls. The material used is Weber's plastic insulating cement and its appearance on the walls of the checker chambers is shown in Figs. 2 and 3. Two monolithic coats of the cement, each having a thickness of 1 in., were applied to the walls of the chambers, the spreading capacity being about 1,000 sq. ft. to the ton, 1 in. thick. The tank bottom is built of 12-in. vacuum-cast flux blocks in the melting end with 18-in. blocks in the nose and the six ports are constructed of super-duty fire-brick, all of this material being furnished by the Walsh Refractories Corporation, together with the checker tile in the regenerators. Corhart blocks were used in the side walls and throat, and the 14-in. crown was furnished by Harbison-Walker.

The flow of producer gas and combustion air to the tank is controlled by an Amsler-Morton air valve and a Wellman reversing valve. The flue leads outside and along the side of the building to a new stack which was a part of the rebuilding project and is shown in Fig. 4. Natural gas burners are located at the ports for emergency use, such as during the recent coal strike when the shortage of coal necessitated the use of natural gas for a time. The new steel stack is of the self-supporting type, 110 ft. high and 6 ft. in diameter. The furnace flue enters the stack near the bottom, and another flue for burn-out gases enters at a higher level. The stack is lined throughout with 4½-in. firebrick and has clean-out doors at the bottom.

The furnace pressure is automatically controlled, the recording and control instruments being mounted on a panel in a corner of the building at the rear of the tank, as shown in Fig. 5. At the top of the panel is a Republic continuous pressure recorder and at the center is the

handwheel for adjusting the Askania furnace-pressure regulator to hold any desired pressure constantly in the tank. A 2-in. impulse pipe leads from a hole in the crown of the furnace to the regulator and the latter, in turn, automatically controls the stack flue damper through a hydraulic cylinder in the basement, illustrated in Fig. 6. The heavy 780-lb. damper is counterweighted by a weight that hangs from a pulley at the lower end of the piston rod. It is stated that the furnace pressure does not vary more than 0.003 in. in water except at reversals.

In regular operation the proper time for reversal of the furnace is indicated by means of an interesting and ingenious combination of an electric pyrometer and a signal bell. The Brown pyrometer is of the recording type and is mounted on a panel at the rear end of the furnace, as shown in Fig. 7. Thermocouples are located in the checkers at each side of the furnace, the connection to one of these couples being shown in the center panel in Fig. 3. The signal bell circuit is connected to the pyrometer and the mechanism can be adjusted so that the bell will ring when the desired temperature is reached in the regenerator. At present the furnace is reversed when the checker temperature rises to 2,000°F., the time interval between reversals usually ranging between twenty and thirty minutes. The reversing mechanism is operated manually.

Batch is brought to the charging floor in heavy carts, a motor-operated winch and cable being used to drag the carts up the ramp to the charging floor level. The batch is fed to the tank by hand, two doghouses, each 4 ft. square, being located at the back end of the furnace for this purpose. Fig. 8 shows the charging operation and the dust hoods that carry the batch dust away into the exhaust system. At the front end of the new tank the heat-resisting ovenware is formed on four Miller presses.

From the presses the ware is carried into the lehr and

Fig. 5. This panel carries the Republic furnace-pressure recorder at the top and the Askania pressure regulator with its adjusting handwheel at the center. On the floor in front of the panel is the motor-operated winch for drawing batch carts up the ramp to the charging floor.

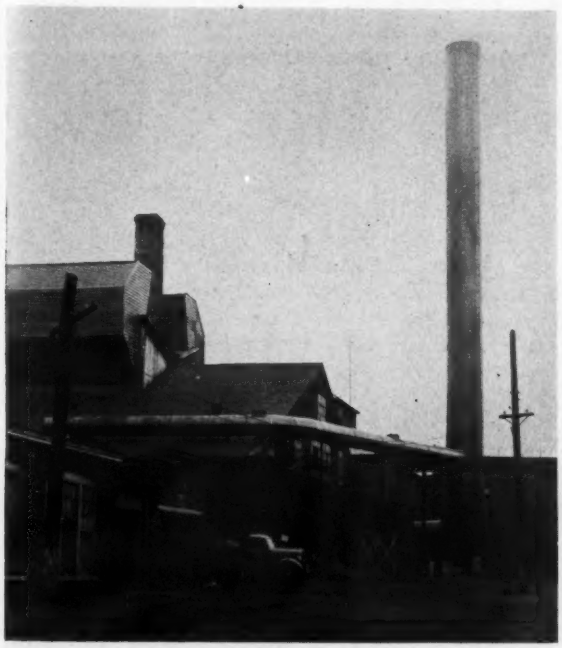


Fig. 4. This view of the south end of the factory building in which the new No. 3 tank is located also shows the new 110-ft. steel stack. The long horizontal flue carries burn-out gases from the lehrs.

Fig. 6. The damper-operating cylinder of the Askania pressure regulator is located near the stack flue in the basement. The damper counterweight is attached by pulley to the lower end of the piston rod.

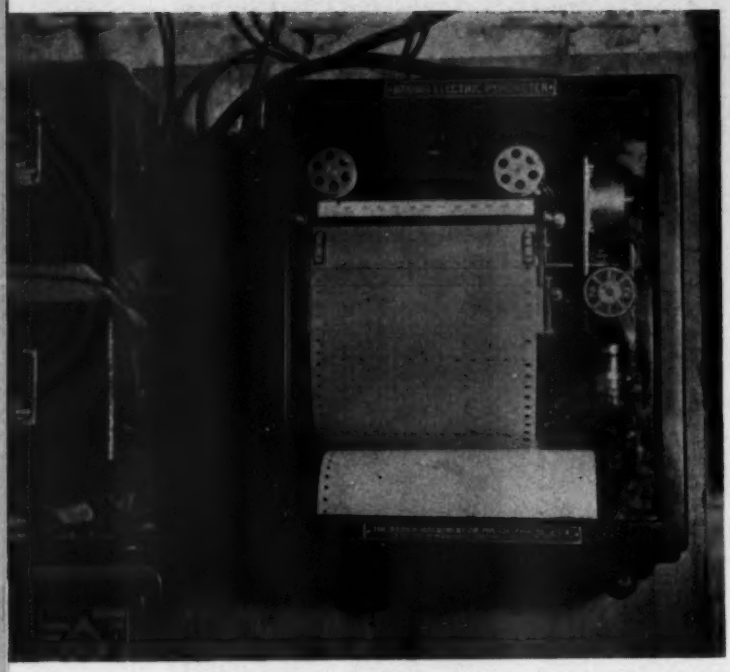


Fig. 7. A Brown electric pyrometer records temperatures in the checkers on both sids of the furnace and automatically rings a signal bell when the checker temperature has reached the proper point for reversal of the furnace.

Fig. 8. The new No. 3 tank is charged through two doghouses, each of which is fitted with dust hoods connected to an exhaust system. On the wall at the left is the electric pyrometer for the reversal signal system.

Fig. 9 shows the lehr being charged with a trayful of Glasbake pie plates. This new Amsler-Morton lehr is of the muffle type with a wire-mesh belt, as are four of the other fifteen lehrs in the McKee plant. The lehr tunnel is 10 ft. wide and 85 ft. long, the belt speed being about 5 in. per minute. This lehr is fired with natural gas. At the discharge end of the lehr the ware is inspected right off the belt, selected ware being placed in cartons immediately for shipment or storage. Ware with small scratches, or fins, that can be reclaimed by buffing and polishing is sent to the finishing department. Some of the ware is also decorated in various ways before being packed. Filled cartons travel from the packing position at the end of the lehr on a Mathews gravity roller conveyor system which is also a part of the modernization program at McKee Glass. In the shipping room one girl inspects and seals the cartons and from the shipping room a double-deck conveyor carries the cartons on the lower deck to the stock rooms, the upper level transporting the boxes to railroad cars for immediate shipment. This tansportation system employs 1,500 ft. of 26-in. conveyor with slopes varying from ½ to 5 per cent. At present it is not being used to capacity but is handling about 4,800 cartons per day with very appreciable savings in time and labor.

The finishing department performs such operations as grinding, polishing, buffing and decorating. About 25 men and women are employed in this department and one function is the reclamation of ovenware that has been set aside by the inspectors because of small scratches or fins. Such work is done on grinding and polishing wheels of various sizes and shapes. In Fig. 11, the operator is removing a small fin from an otherwise perfect casserole cover. Other workers in this department are

Fig. 9. Charging end of the new 10- by 85-ft. Amsler Morton lehr in which the ware from No. 3 tank is annealed. The lehr is of the muffle type and is fired with producer gas.

Fig. 10. At the discharge end of the lehr the ware is inspected right off the wire-mesh lehr belt and selected ware is packed immediately. This view also shows a section of the Mathews gravity roller conveyor system that serves the inspection, shipping and stock rooms.

employed at horizontal and vertical grinding wheels smoothing and finishing edges of coffee brewers, water coolers, lantern globes, sanctuary lights, and so forth. In the nearby decorating room operators are engaged in hand-painting, stenciling and decorating kitchen ware, Glasbake ovenware, lenses and other special types of ware. Specialty work such as the spraying of fog lenses with a weather-resistant stain is also accomplished in this department. All decorated products are fired in an Amsler-Morton decorating lehr.

In addition to the types of ware already mentioned, the McKee line includes opaque and crystal dinnerware, auto, airport, marine and traffic lenses, tubing, chemical ware, American Prescut tableware. It also does a large amount of special work, an interesting example of which was the recently completed contract for 1,100,00 pieces of special glass tile for the Queens Midtown tunnel in New York. The specifications for this tile included a greater than average tensile strength, a limited coefficient of expension, a dense ivory color and a light reflecting factor of 85 per cent. McKee Glass Co. was able to follow these rigid specifications without trouble and to ship the finished tile in a remarkably short time.

During the 52 years that have elapsed since Sellers McKee first located his glass works in what is now Jeannette, the McKee Glass Co. has come to be one of the most versatile of glass manufacturers. With this wide branching out into diverse products and markets, however, the modernization of equipment and processes has not been neglected and the new ovenware production unit exhibits the application of proper glass engineering principles for plant rehabilitation and betterment.

Fig. 11. In the finishing department small fins and scratches are removed from otherwise perfect ware in this manner.

DENSITY OF GLASSES AS A FUNCTION OF COMPOSITION

As part of the Bureau of Standards' investigation of the variation in density of glass with composition, J. C. Young, F. W. Glaze, and C. A. Faick, under the direction of A. N. Finn, analyzed and determined the densities of a large number of glasses made from varying amounts of powdered quartz crystals, soda ash, and potash, which had been melted in platinum crucibles in a platinum resistance furnace.

As reported in the April number of the *Journal of Research* (RP1197), it was found that, between certain compositions, the specific volumes of the glasses vary linearly with composition, and that the limiting compositions correspond to the eutectic compositions determined by studying the crystallizing characteristics of molten glass.

GRADUATES OF CERAMIC COLLEGES OFFER SPECIALIZED TRAINING

This June, as every June, the various ceramic colleges have graduated trained young men who are eager to build careers for themselves in the glass industry. In addition to their general training in the technics of glass production, each of these young men has specialized in a particular problem facing glass plants as the subject for his graduation thesis. THE GLASS INDUSTRY is publishing a list of the graduates of three of the ceramic colleges with the idea in mind that the various glass manufacturing companies and others closely identified with the industry are often confronted with problems for which specialized training is required. It is hoped that the publication of this list will perform a dual service to both the glass and allied companies and to the graduates themselves.

As a corollary, it is suggested that many glass companies might find it advantageous to give summer employment to ceramic undergraduates, particularly during their Junior year. This would enable specific companies to become acquainted with individual undergraduates and rate them as to technical ability, personality and fitness for their organizations. Following is a list of this June's graduating students, both graduate and undergraduate, together with the subjects of their specialties:

New York State College of Ceramics: Russell J. Barreca, "Toughening Glass"; George H. Batley, "Toughening Glass"; Raymond J. Buckley, Jr., "Silica-free Glasses"; F. Kenyon Clarke, "Currents in Glass Tanks"; Martin E. Dykeman, "Refractories"; Jack Feurstein, "Amber Glasses"; Willis G. Lawrence, "Spectrographic Study of Glass Sands"; Olaf M. Loytty, "Tellurium in Glass"; Joseph P. Majeske, "Specific Heat of Glass"; John R. Masters, "Surface Combustion"; Herbert J. Mossien, "Tellurium in Glass"; Robert F. Plumridge, "Compound Glass Rods"; Addison B. Scholes, "Currents in Glass Tanks"; Herman Shrickel, "Compound Glass"; Seymour Smigrod, "Silica-free Glasses"; Donald J. Tucker, "Spectrographic Study of Glass Sands"; Munroe F. Veazie, "Specific Heat of Glass."

Pennsylvania State College: Professor N. W. Taylor, head of the Department of Ceramics, writes that he is enclosing a list of graduate students who have completed their theses as well.

Bachelors of Science: Wm. P. Bramlett, Jr., "Silver as a Coloring Agent in Glass"; Kenneth S. Cowlin, "Fluorescence Produced by Silver in Glass"; George R. Henry, "Particle Size Studies and Distribution of Heavy Mineral Impurities in Glass Sand"; George J. Morris, "Refractory Laboratory Ware from Bonded Periclase"; Lee O. Upton, "Study of Solarizing Glasses for Ultra-Violet Measurements."

Masters of Science: Robert F. Doran, "Elastico-Viscous Properties of Potash Glasses in the Annealing Range"; Otto C. Klein, "A Study of Strain in Glass by X-ray Methods"; Mrs. Meta G. Neuberger, "The Beneficiation of a Glass Sand by the Method of Flotation"; Cho-Yuan Lin, "The Effect of Various Catalysts on the Conversion of Quartz to Cristobalite and Tridymite at High Temperatures."

University of Illinois: R. L. Shute, Cer. Eng., "Some Recent Developments in the Construction and Operation of Glass Furnaces"; F. V. Tooley, Ph.D., "Factors Affecting Glass Durability Tests"; A. E. Badger, Ph.D., "Colloidal Colors in Glass"; J. F. White, M.S., "Electrical Conductivity of Glass"; F. M. Fraulini, M.S., "Effect of Lithium Oxide on Some Properties of Glasses"; H. J. Beckmeyer, M.S., "Melting and Fining of Glasses as Affected by Calcium Fluoride"; B. Bard, M.S., "Colors Produced by Reduced Oxides in Glasses."

● *Lists of Juniors and other undergraduates available for summer employment may be obtained by writing either to the colleges or to* THE GLASS INDUSTRY.—*The Editor.*

NEW SPECTACLE LENS MAGNIFIES 300 PER CENT

At the annual meeting of the American Academy of Optometry in Los Angeles this month, a new type of spectacle lens with a magnification of 300 per cent was described. It is called a teleoptic-magnifier and resembles a glass cone. The lens is one inch long and consists of a combination of from three to five lenses for each eye and is light enough to be fitted into ordinary eyeglass frames. Dr. William Feinbloom, a research fellow at Columbia University, reports that it has been successfully applied in twenty cases of optic nerve atrophy and that seven children in blind institutions had already been returned to public schools through its use.

INSTITUTE OF CERAMIC ENGINEERS ELECTED TO AMERICAN ENGINEERING COUNCIL

The Institute of Ceramic Engineers reports that it has been elected to the American Engineering Council, which is one of several engineering groups which has been promoting the professional activities of engineers and in this particular instance with a principal view to public relations. The American Engineering Council was created almost 20 years ago to provide concerted action by engineers on social and economic questions. The preamble to the Council's constitution states that its object "shall be to further the public welfare wherever technical and engineering knowledge and experience are involved, and to consider and act upon matters of common concern to the engineering and allied technical professions."

ILLUMINATING ENGINEERS TO MEET

For the first time in its history, the Illuminating Engineering Society will hold its convention on the Pacific Coast. Its 33rd annual meeting will be held in San Francisco from August 21st to 25th inclusive, with headquarters at the Hotel Fairmont. One of the principal features of the meeting will be visits to the Golden Gate International Exposition, papers on whose illumination are scheduled for presentation. Since a regular itinerary has been planned, particularly as far as Eastern members are concerned, it is suggested that those interested in attending the meeting communicate with the Illuminating Engineering Society, 51 Madison Avenue, New York City.

CHEMICAL INDUSTRIES EXPOSITION

The 17th Exposition of Chemical Industries will be held this year at the Grand Central Palace, New York City, during the week of December 4 to 9.

ANALYSIS OF STRAINS AND STRESS IN GLASS
IV—PRINCIPAL STRESSES AND THEIR EVALUATION

By A. J. MONACK* and E. E. BEETON
WESTERN ELECTRIC COMPANY, INC.
VACUUM TUBE SHOP

The last article of this series takes up isochromatic and isoclinic lines and their significance; and outlines the construction and use of the circular polariscope. Lines of principal stress are also discussed, and methods for evaluation of stresses in glass are explained.—The Editor.

The value of (P—Q) in the stress equation, $R = C(P—Q)d$, corresponds to a definite interference color in a plate of strained glass of a certain thickness. If the thickness is uniform over the whole plate it is evident that wherever the same color occurs in the plate, using polarized light (and a sensitive tint plate unless the glass is relatively thick), the values of (P—Q) at these points must be equal. Thus, wherever a yellow color occurs, (P—Q) has a certain value; and wherever green occurs, (P—Q) has also a certain value which differs from that corresponding to a yellow color. The colors must always be of the same "order" and, of course, a second-order yellow is not equivalent to a first-order yellow (See Table I). With monochromatic light, black bands are obtained instead of bands of color, values of (P—Q) being equal along any black band, and other values of (P—Q) being interpolated between successive black bands. Lines of equal (P—Q), whether colored or black, are called *isochromatic lines.*

The photoelastic constant for glasses is much lower than that for such materials as celluloid, Bakelite, etc., and the strain pattern is generally a black-and-white pattern unless the glass is very thick. Consequently, little or no color is obtained. A sensitive tint plate can be used to overcome this condition, although difficulties are introduced by the fact that in many cases the colors will be opposite in opposite quadrants. The tint plate in such cases must be used in two quadrants, then turned 90 deg. for use in the other two.

It is possible, then, by means of a graduated quartz wedge or a Babinet compensator, to determine the value of (P—Q) at any point in the plate of strained glass, taking only a comparatively small number of measurements and utilizing the isochromatic lines. Such lines and values, however, are of little use unless coupled with the lines of principal stress, and the next step, therefore, must be to determine the lines of principal stress.

Isoclinic Lines

In the earlier discussion of a specimen of glass under simple tension it was stated that when the direction of stress was parallel with the direction of vibration of the polarizer or analyzer the specimen appeared dark in the polariscope. The same effect was obtained with simple compression. In the case of any plane stress system, darkness also results wherever the principal stress directions are parallel to the vibration planes of the polarizer and analyzer. This fact makes it possible to map out the directions of principal stress in a glass specimen under investigation.

Suppose, for instance, the strained glass plate shown in Fig. 30 is placed in a polariscope having vibration planes XX and YY of analyzer and polarizer, respectively. Suppose, further, that a black line is seen, as shown dotted in the figure and marked "0 deg." At any point along this line it is known that, since darkness results, the directions of principal stress must be parallel to XX and YY and the crosses indicate these directions at a few selected points. Such a dark line as this is known as an *isoclinic line,* because the principal stress directions at any point along the line are equally inclined to the reference axes.

Now let the polarizer and analyzer be rotated together in a clockwise direction until YY reaches the axis marked "10 deg." The polarizer and analyzer are still at right angles, and must be kept so in what follows, but a new black line has appeared, and the first one has vanished. The new isoclinic is also shown dotted and marked "10 deg."; the principal stress directions are again parallel to the vibration planes of polarizer and analyzer; and these directions are again shown by small crosses whose arms parallel XX and YY in the new position. The polarizer and analyzer are successively rotated to the position marked "20 deg.", where a third isoclinic appears, marked "20 deg.," and the small crosses again show the principal stress directions.

After the process has been repeated through a rotation of 90 deg. the principal stress directions are known throughout the plate and by using care in the selection of the points, the full lines shown in Fig. 30 can be drawn in. These are the *lines of principal stress.* A more accurate method of drawing in these lines can be used instead of the small crosses, but is usually not necessary. A line of principal stress (there are two kinds, P-lines and Q-lines) is a continuous curved line, such that the tangent to the line at any point gives the direction of principal stress. The P-lines and Q-lines must always cross each other at right angles.

If a tint plate is used with the polariscope, the isoclinics will not be black lines, but will have the same first-order red color obtained with the tint plate alone in the polariscope. The tint plate would have to rotate with the polarizer and analyzer and, consequently, it is just as well to determine the isoclinics from the black-and-white pattern usually obtained with glass of moderate thickness when no tint plate is used.

In determining the isoclinics it is necessary to have both polarizer and analyzer equipped with scales to show the amount of rotation, the most convenient arrangement locating the "zero" of the polarizer dial on

*Now with RCA Manuacturing Company, Harrison, N. J.

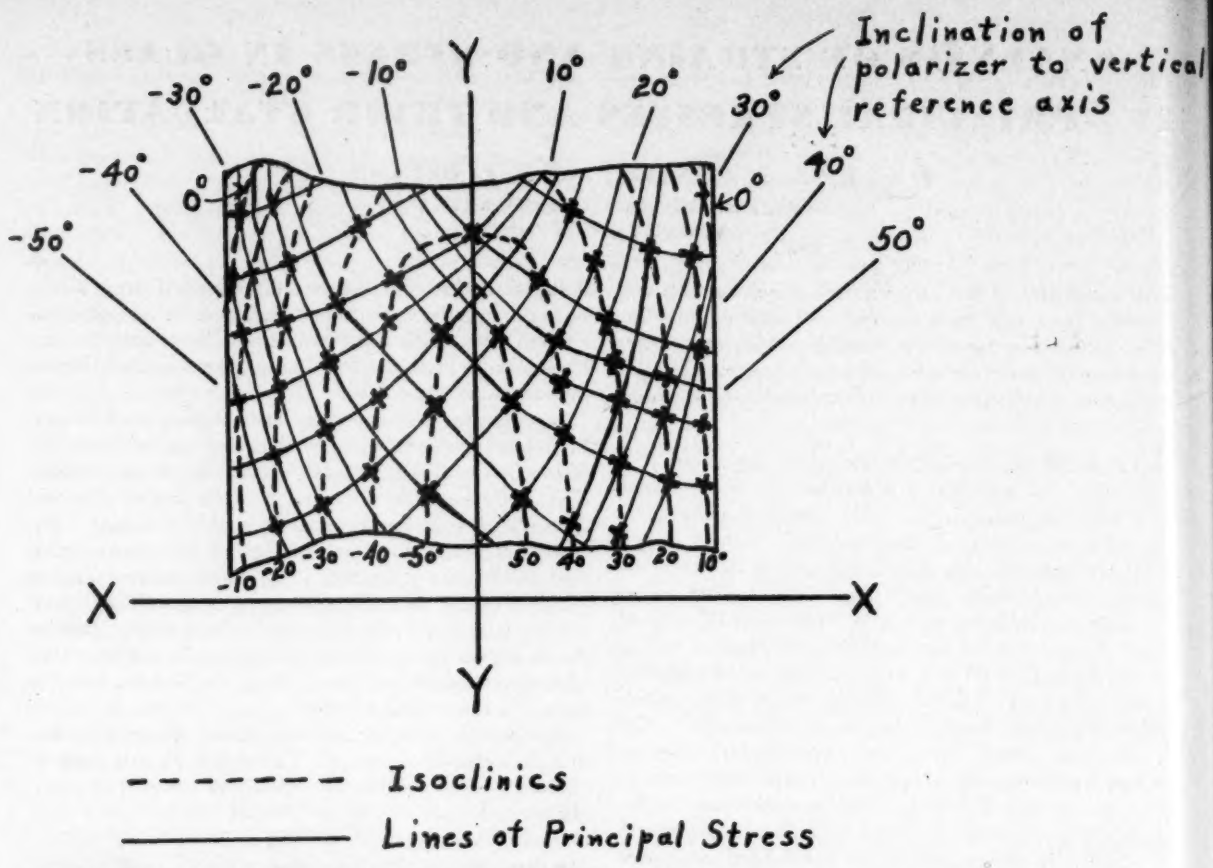


Fig. 30. Isoclinics and lines of principal stress in a plate of strained glass.

the top with the scale running in a counter-clockwise direction, while the "zero" of the analyzer is in a horizontal direction at 90 deg. clockwise from the polarizer "zero" and the scale also running counter-clockwise. Both polarizer and analyzer are then rotated in a clockwise direction to the same scale reading on each dial when the isoclinics are to be mapped out.

The Circular Polariscope

A circular polariscope consists of a polarizer and analyzer in crossed position with two quarter-wave plates between them, one on each side of the specimen to be examined. The first quarter-wave plate has one of its vibration directions at 45 deg. to the vibration direction of the polarizer, the other quarter-wave plate having its vibration directions at right angles to those of the first. Fig. 31 shows a circular polariscope diagramatically.

The use of the circular polariscope can best be understood by considering what happens when plane polarized light passes through a quarter-wave plate. Quarter-wave plates are made by cementing a crystal section, usually mica, between two pieces of glass. The crystal must be birefracting and the section is cut so that it is parallel, or nearly so, to the optic axis of the crystal. From what has already been said, it is known that when plane polarized light passes through a birefracting plate it is broken up into two plane polarized rays, the O ray and the E ray, vibrating in planes perpendicular to each other and traveling through the crystal with different velocities. Thus, for any crystal, the amount which one ray falls behind the other while traversing the crystal section is proportional to the thickness. Since quarter-wave plates produce "circularly polarized" light, it would be expected that "circularly polarized" light consists of two rays, one of which falls behind the other by one-fourth of a wavelength, and this is exactly what happens.

Since the quarter-wave plates are placed in the polariscope with their axes at 45 deg. to the polarizing axes, the amplitude of the O ray equals that of the E ray and a retardation of one-quarter wavelength corresponds to a phase difference of 90 deg. Thus, after traversing a quarter-wave plate, the plane polarized light has been transformed into two rays of equal amplitude vibrating at right angles to each other and differing in phase by 90 deg. Any two periodic vibrations of equal amplitudes, executed at right angles to each other and differing in phase by 90 deg., are equivalent to a uniform circular motion, the radius of the circle being equal to the amplitude of either vibration. Hence, light originally plane polarized is termed "circularly polarized" after passing through a quarter-wave plate.

A quarter-wave plate can only be made for light of a definite wave-length and it is necessary, therefore, to use a monochromatic source of light with a circular polariscope. However, the thicknesses of the plates need not be such as to give a quarter-wave retardation precisely, and the wavelength of the light used need not be precisely that for which the plates were calibrated. Mindlin[12] has shown that if the quarter-wave plates produce identical

[12] R. D. Mindlin, *J. Opt. Soc. Amer.*, 27, 288-291 (1937).

retardations the fringe pattern is unaffected except for the incomplete removal of the isoclinics. A polariscope in which the plates produce identical retardations, but are not true quarter-wave plates for the light used, is known as a balanced polariscope.

The great advantage of the circular polariscope is the elimination of the isoclinics. Since monochromatic light is used, the pattern obtained consists of a series of black lines, these black lines being the isochromatics. As explained previously, isochromatic lines are lines of equal (P—Q) and, at any point along such a line, (P—Q) will have the same value. Furthermore, interpolation between two neighboring isochromatics will give the value of (P—Q) for the intermediate point. Hence, if one measurement of (P—Q) is made on each isochromatic the complete evaluation of (P—Q) throughout the system is possible. If the circular polariscope is not used this is more difficult, because the isoclinic lines very often cause confusion. The confusion arises because the isochromatics appear as colored bands when white light is used, while the isoclinics are black bands and a black isoclinic may appear at just the point where a value of (P—Q) is desired.

The circular polariscope has the added advantage that the stress directions in the specimen being studied need not make any specified angle with respect to the axes of the polarizer and analyzer.

Lines of Principal Stress

It is well to keep in mind the following points concerning lines of principal stress.

1. The lines of principal stress have continuous curvature.
2. A concentration of stress is shown by convergent lines of P-stress or Q-stress, or both, divergent lines showing decreasing stress.
3. Uniform stress variation is shown by parallel lines of principal stress.
4. The P-lines and Q-lines must intersect at right angles.
5. At a free boundary one system of stress lines must be at right angles to the boundary, while the second is tangential.
6. The stress normal to a free boundary is zero.
7. P is taken as the algebraically greater stress, tension being considered as a positive and compression as a negative stress.

Effects of Variation of Stress Through the Thickness

All of the previous discussion has assumed that the thickness of the glass has been small with respect to the other dimensions, but if the plate is thick, both the directions and magnitudes of the principal stresses vary in general from layer to layer. If the directions of the principal stresses are constant throughout the thickness, the retardations due to the various layers simply add, and P and Q becomes the principal mean stresses in the plate. At a free boundary this condition is satisfied, since at such a boundary all stresses must be normal or tangential to the edge. Away from the edge the directions usually vary from layer to layer. If the thickness is one-quarter inch or less and the area normal to the thickness is two square inches or more no great error is introduced if the system is considered one of plane stress. In any case there is a method of checking. If the isoclinics are no longer intensely black it can be assumed that the directions of principal stress vary noticeably from layer to layer. Any measurements made in such areas must be accepted with caution.

Photoelastic evaluation of a stress system referred to three axes at right angles to each other has not yet been developed. There are at present two lines of research which are being applied to stress studies in plastics, but which, by extension, will furnish useful information for stress analyes in glasses. The first of these methods relies upon a unique property of certain plastics, which permits the plastic to retain at room temperature the stress pattern imposed by loading at an elevated temperature and cooling slowly. A plastic model so treated can be sliced, and the stress distribution in each slice can be determined. The second method makes use of the polarization caused by the scattering of light within a cloudy model. The model is made from a transparent plastic which contains enough scattering particles to permit satisfactory analysis of a beam of polarized light. A beam of collimated plane-polarized light, passed through a slit, illuminates a plane section through the loaded model, and interference fringes appear in this section when viewed normal to the beam. Here the stress is a function of the spacing of the fringes rather than of the fringe order. It is likely that this second method can be used directly in the case of glasses, while the first method can be applied only indirectly.

Apparatus for Photoelastic Stress Determinations

The use of polarizers and analyzers equipped with scales to permit easy settings when the isoclinics are mapped out is extremely important. It is possible, of course, to rotate the specimen instead of the polarizer and analyzer, but there are objections to this method on the grounds of accuracy and convenience.

In order to make a photoelastic stress evaluation it is necessary to refer the isoclinics and lines of principal

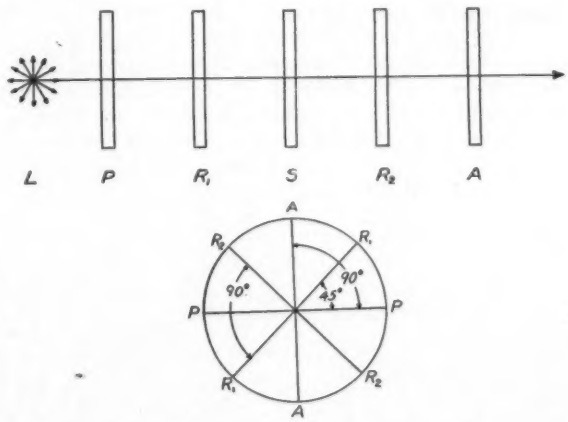
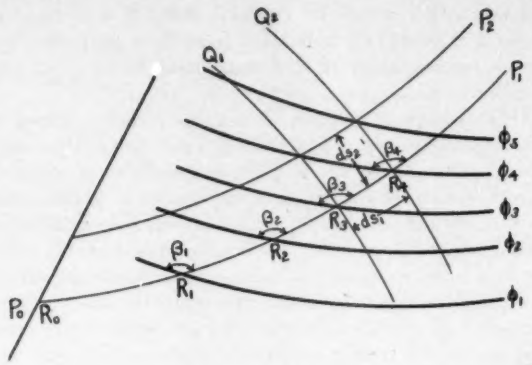


Fig. 31. Schematic diagram of circular polariscope (above) with orientation of its parts (below). L—Monochromatic source of light; P—Polarizer; R_1 and R_2—Quarter-wave plates; S—Specimen; A—Analyzer. PP—Vibration direction of polarizer; AA—Vibration direction of analyzer; R_1R_1—Vibration direction of fast ray of first quarter-wave plate; R_2R_2—Vibration direction of fast ray of second quarter-wave plate.

Fig. 32. Determination of angle β for graphic integration of stress.



stress to reference axes and, as a rule, it is best to project the image of the plate to be studied on a screen of ground glass or a sheet of tracing paper. At the same time it is well to project the image of a rectangular network of reference which is supported against the face of the specimen. This network should be traced on the paper at the same time that the other lines are traced; or a standard network of reference may be printed photographically upon a glass plate, and this plate used with the specimen.

Instead of tracing the bands visually, the image of specimen and network may be photographed, but in this case it is almost essential that monochromatic light be used. Isochromatics and isoclinics will look alike, of course, but since a series of photographs would have to be taken for different settings of polarizer and analyzer, the isochromatics would be evident, since these lines do not change position. The fringe order could be obtained in this way. The use of colored film transparencies or prints is another excellent method for use with white light, provided the thickness is great enough to produce color, or if a tint plate can be used. The circular polariscope can be used to eliminate isoclinics where only the isochromatics are required.

It is necessary to know values of (P —Q) at selected points in order to employ graphical integration for the determination of the principal stresses separately. This may be done with the graduated quartz wedge or the Babinet compensator. Wherever a line of principal stress cuts an isoclinic the value of (P —Q) should be measured and for such measurement the wedge or compensator should be placed with its axes parallel to the lines of principal stress at the desired point. The polarizer and analyzer should then be rotated so that their vibration planes make a 45-deg. angle with the vertical and horizontal reference axes, while the vibration planes of polarizer and analyzer are kept perpendicular to each other. When an extinction position is reached it is, of course, necessary to rotate polarizer and analyzer to another position, say "0°". (P—Q) values may be interpolated from the isochromatic lines, and generally this represents a great saving in time.

All necessary measurements have now been made:

1. Mapping the isoclinics, and giving each a value ϕ of the angle of rotation of polarizer and analyzer.
2. Constructing the P and Q lines of principal stress.
3. Measuring values of (P —Q) at selected points.

All equipment necessary for these operations has been described and, with these data, the values of P and Q can be separated by means of graphical integration.

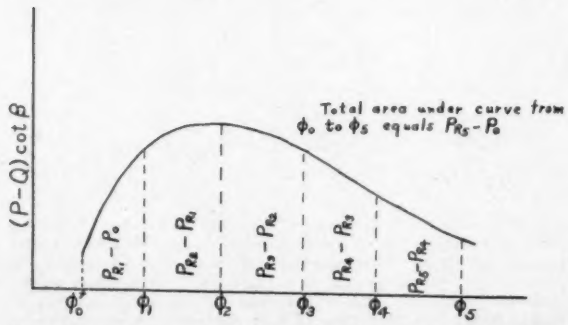


Fig. 33. Graphic method for evaluation of stress at selected points.

Graphical Integration

There are several methods of graphical integration, but only two modifications of one method will be explained here. In this method a line of principal stress is followed and the values of P are determined at selected points along this line. (P —Q) being known, it is possible to compute Q for the given point. With values of P and Q known at any point, a mere extension of the method permits similar integration along any other line through the known point. By this system of traveling along lines of principal stress the entire stress system is made known.

In Fig. 32, P and Q are principal stress lines; ϕ_5, ϕ_4 ϕ_3, etc., indicate isoclinics, where ϕ_5, ϕ_4, ϕ_3, etc., are also the angles through which the polarizer and analyzer have beeen rotated in order to obtain the isoclinics. R_1, R_2, R_3, R_4 are the points at which P and Q stresses are to be determined along the line P_1. The unknown which must be determined is the angle β. This is the angle through which the tangent to the P-line at the selected point, say R_3, has to be rotated in a counterclockwise direction in order to become tangent to the isoclinic through the selected point. Values of β must be measured at every point where it is desired to know P and Q.

It is necessary to start graphical integration from a point of known stress, and a free boundary offers the logical starting point. At such a boundary one line of principal stress is always normal to the edge and the other is tangential. The normal stress at the edge must be zero, and this may be P or Q. In Fig. 31 P_0 is normal to the edge, and consequently its value is zero. This is a starting point for integration along the line P_1. The Q stress at that point is computed from the relation $Q = \frac{R}{Cd}$

The table below is a convenient form for the computation of P. P_0 is always the stress at the starting point and need not always be zero, but may be any known stress at any point on the line being followed.

Point	β	cot β	(P-Q)	(P-Q) cot β	ϕ	Area	p-p_0	p-p_0) (.01745 × P—P_0	P
R_0	β_0	cot β_0	$(P\text{-}Q)_0$	Product	ϕ_0				O
R_1	β_1	cot β_1	$(P\text{-}Q)_1$	"	ϕ_1	A_1	p_1-p_0	M_1	P_1
R_2	β_2	cot β_2	$(P\text{-}Q)_2$	"	ϕ_2	A_2	p_2-p_0	M_2	P_2

(where A_1 is the area from ϕ_0 to ϕ_1, A_2 from ϕ_0 to ϕ_2, etc.)

The table requires explanation. The points considered are in the first column, and may be given any designation. β has been explained, and it is shown in Fig. 32. (P-Q) is measured at the point being investigated. ϕ is the angle through which polarizer and analyzer have been rotated to give the isoclinic through the point being measured. The column headed "Area" introduces a new term, which is explained by Fig. 33. (P-Q) cot β is plotted against ϕ. ϕ_0 is the isoclinic which passes through the point P_O of known stress. The area under the curve between the value of ϕ for the reference point of measurement and the point under investigation (shown by ϕ_0 and ϕ_3, respectively) is determined by means of a planimeter, Simpson's rules, or any other method. This area is equal to $(p\text{-}p_0)$. If ϕ is measured in degrees, the value of $(p\text{-}p_0)$ must be multiplied by 0.01745 to obtain $(P\text{-}P_O)$, where P_O is the stress at the initial reference point, i.e., at a free boundary or a point of known stress, and P is the stress at the point under investigation. If ϕ is measured in radians, the area gives $(P\text{-}P_O)$ directly. Since P_O is known, P can be computed. Since (P-Q) is known, Q can also be computed.

The method is similar for integration along a Q-line, with the exceptions that β is replaced in the table by $(\beta\text{-}90°)$, and $(P\text{-}P_O)$ is replaced by $(Q_O\text{-}Q)$.

Starting from points evaluated on a line of principal stress, other lines of principal stress, may be followed until the complete stress system has been determined. It is always necessary, however, to start with a point of known stress, since graphical integration can not be used without a starting point.

There is an alternative method of graphical integration, explained by Fig. 34. The method is made easier if the differences between the angles of rotation of polarizer and analyzer are made constant, but never more than 5 degrees. Take the point A in Fig. 34. P_1 and P_2 are neighboring lines of principal stress, as are Q_4 and Q_5. The distance between Q_4 and Q_5 is called ds_4, and is measured. The distance AD between the isoclinics at A and D (always perpendicular to the line along which integration is being performed) is also measured, and called $\triangle s_2$. The angle of the isoclinic through the point is noted, and is subtracted from the angle of the next higher isoclinic to give $\triangle\phi$. A figure similar to Fig. 33 is drawn by plotting $(P\text{-}Q)/\triangle s_2$ against S_P as abscissa, where S_p is the sum $(ds_0 + ds_1 + ds_2 \ldots . + ds_A)$ from the point of known stress to the point under investigation. The data are tabulated under the following headings:

Point No.	$\triangle s_2$	(P-Q)	(P-Q) / $\triangle s_2$	S_P	Area	P_O-P ($\triangle\phi$ x Area)	P

Integration along a Q-line is performed similarly, by taking ds_3 as $\triangle s_2$, AD as a ds_Q unit (see Fig. 34), S_Q for S_P, $(Q_O\text{-}Q)$ for $(P_O\text{-}P)$, and Q for P.

This second method is useful when the isoclinics are nearly parallel with the principal stress line along which integration is being performed, and must be used in those rare cases where an isoclinic coincides with a line of principal stress throughout its length.

Stress in Complex Glass Shapes

A promising method, though used little so far, if at all, for stress distributions and analyses in complex glass shapes is that in which a model of the shape to be investigated is pressed from an organic plastic material, such as bakelite, phenolite, or marblette, which facilitate stress studies because of their relatively high photoelastic constants. By use of a proper plastic, a three-dimensional stress analysis could be made by slicing sections of a model which had been cooled slowly under load. Use of models made from plastics is of value chiefly for the study of mechanically-induced stresses, although the method should also find some application in cases of thermally-induced stresses. The circular polariscope is very helpful with organic plastics, and should be considered in connection with the methods discussed here.

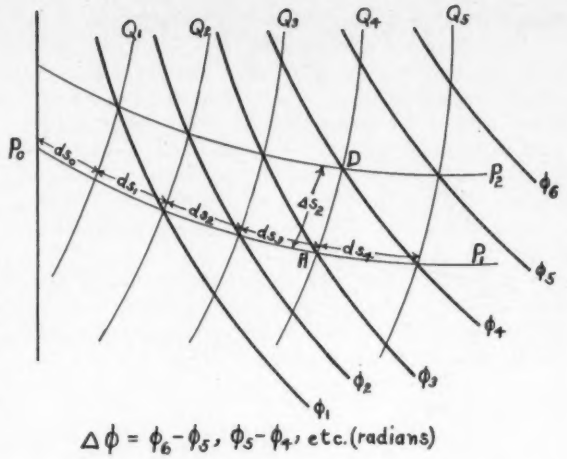


Fig. 34. Graphical integration by the intercept method.

Conclusion

An attempt has been made here to cover all pertinent points which aid in an understanding of strains and stresses in glass. No true knowledge of the subject can be obtained without at least an acquaintance with the mechanics and optics upon which the entire structure rests. This has been given with complete elimination of all extraneous matter, but all important information has been covered in a more or less detailed way. The compression necessary to restrict the length to a reasonable amount has, of course, meant the elimination of some details of interest and value. The criterion was, "Is it worth while for the glass technologist to know this?" If the answer was negative the point in question was omitted. In keeping with this policy, mathematical treatments are practically non-existent, physical explanations being preferred in every case.

It should be evident by now that strains and stresses in glass are more than a matter of mere color in the polariscope. Many factors influence the colors seen and, in general, each color visible in the polariscope, or each retardation measured, is the difference, (P-Q), of two stresses at right angles to each other. Nor does absence of color always mean absence of stress, since darkness results when P-Q equals zero. Fortunately, such cases are not common. The presence of color, however, is not alone a measure of the dangerous stresses in glass.

It is, to be sure, a measure of the maximum shear, that is, (P-Q)/2, which is of importance in predicting failure in ductile materials but has little value for a like purpose with respect to glass. The stresses must be separated, and a method for doing this has been indicated. For work which does not justify the effort and time required for such separation it may be sufficient to note the absence of strain in all parts of the glass, since a zero value of P-Q is not likely to occur in every part of the glass.

It is possible that the compressed treatment given here on photoelastic methods and meanings may lead to a desire for fuller understanding. In order to make this possible the following brief bibliography is added.

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CRITICISM AND REBUTTAL ON "ANALYSIS OF STRAINS AND STRESS IN GLASS"

The Editor of THE GLASS INDUSTRY

Dear Sir:

"I have been reading the second instalment of Monack and Beeton. There were errors in the physics of the first instalment, and I notice what appears to be a complete misconception in the second section. In the first paragraph for instance, we read, 'Anisotropic crystals are divided into two classes, uniaxial and biaxial, but since strained glass behaves as a uniaxial crystal, it will not be necessary to discuss the biaxial variety.' This is the same mistake that Morey made in his book. Strained glass is normally biaxial and is only uniaxial when the stress is uniaxial, that is, under the conditions of Figure 12 on the next page. Since this condition is exceptional and merely a 'limiting case,' it will apply in a vanishing proportion of specimens examined at random. The truth, therefore, is the exact opposite of that reported by your authors in their first paragraph.

"Table II on page 189 occurs so far separated from the explanation in section *e* on page 190 that I am afraid it is going to produce the wrong impression. This wrong impression will be helped by Figure 17, because people will look at the figures and tables in which certain colors are associated categorically with tension or compression and will not understand that by merely turning the specimen through 90 degrees, all the phenomena will be inverted.

(Signed) *Frank W. Preston*"

The Authors Reply

The Editor of THE GLASS INDUSTRY

Dear Sir:

"We are grateful to your correspondent for pointing out the unfortunate sentence quoted in his letter. The fact that glass in general behaves as a biaxial crystal is of course implicit in the treatment of combined stresses and graphical integration, where the principal stresses correspond to two of the axes of optical symmetry of the biaxial indicatrix. It is simpler, however, to think of the principal stresses as two uniaxial stresses superimposed and acting at right angles.

"If it is remembered that P is always the greater stress and Q the lesser stress, and also that tension is taken as positive and compression as negative, the derivation of the general stress equation follows without difficulty. In the case of stress in a single direction the retardation is given by the equation $R = Cds$, where R is the retardation, C is the photoelastic constant, d is the thickness, and s is the unit stress. If the principal stress P is isolated as a single stress, the retardation caused by this stress is R_P in the equation $R_P = CdP$. If the other principal stress, Q, is isolated as a single stress, the retardation R_Q is given by the equation $R_Q = CdQ$. Principal stresses always act at right angles. Hence at a given point in a strained isotropic substance the retardation measured will be the algebraic difference of the separate retardations. Thus,

$$R_P - R_Q = CdP - CdQ.$$

Removing the common term from the right side gives

$$R_P - R_Q = Cd\,(P - Q), \text{ or}$$

$$R_{diff.} = Cd\,(P - Q),$$

which is the general stress equation in terms of the principal stress difference.

"With respect to the 'errors of physics' mentioned in your correspondent's letter, we are not aware of these. We have merely used conventional petrographic concepts. The objection to the location of Table II seems to us a matter of opinion. It is customary to place a table somewhere near the point where it is first cited in the text. As for possible confusion caused by Figure 17, the reader has only to go on to Figure 18, on the same page, to be set right.

"The great condensation necessary to keep the length of this series of articles to a reasonable limit has doubtless caused some portions to be vague or ambiguous. We shall be grateful to any readers who point out such matters. (Signed) *A. J. Monack, E. E. Beeton*"

PRODUCTION FIGURES FOR THE GLASS INDUSTRY DURING MAY, 1939

Glass Containers: Production of glass containers during May, 1939, was 4,516,178 gross bringing the 1939 total to 19,674,279 gross. Shipments during May were 4,485,253 gross, bringing the 1939 total to 19,174,542 gross.

Plate Glass: The total production of polished plate glass by member companies of the Plate Glass Manufacturers of America during May, 1939, was 8,035,832 sq. ft. as compared to 7,268,068 sq. ft. produced in the preceding month, April, 1939, and 3,866,052 sq. ft. produced in May, 1938.

Window Glass: During May, 1939, the production of window glass was 728,613 boxes which represents 44.8 per cent of industry capacity. As compared with this, May, 1938, production was 360,256 boxes, representing 22.2 per cent of industry capacity.

GLASS CONTAINER INDUSTRY SHOWS IMPROVEMENT

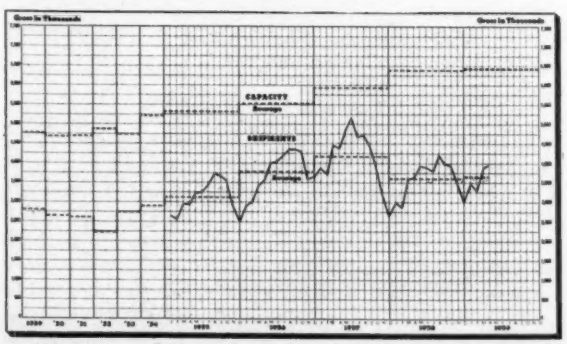
The condition of the glass container industry reflects to date a definite improvement over that of a year ago, according to Victor Hall, statistician of the Glass Container Association, reporting at the semi-annual meeting of the Association at White Sulphur Springs, West Virginia, last month. Shipment for the first quarter of 1939 totaled 3,500,000 gross, exceeding those of the corresponding period of a year ago by 11 per cent.

Production in relation to capacity, however, is considered less favorably, and the industry operated during the first four months of 1939 at only 60 per cent of active operating capacity. Caution is needed, however, in comparing this performance record with former years. Modern methods of glass-making have improved the melting efficiency of furnaces some 33⅓ per cent during the past ten years; so that with no increase in tanks or tank capacities, the industry's productive capacity has increased during this period from 4,700,000 gross per month to 6,400,000 gross per month.

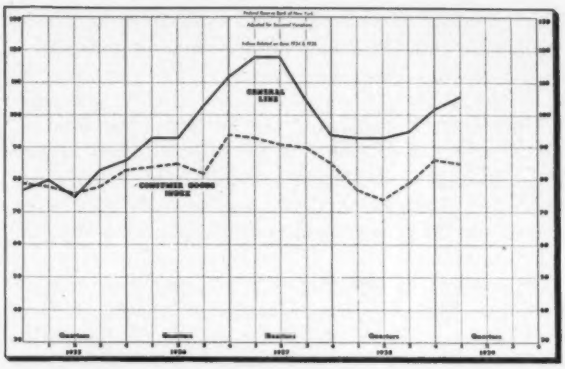
Continuing this analysis, Charles R. Stevenson, business manager of the Association, reported that he failed to see prospects of substantial improvement over the balance of the year. Mr. Stevenson believed that one of the major problems confronting the glass industry was to find sales outlets to take care of this increased productive capacity. In the next five year period, shipments should be stepped up to 100 million gross annually. To accomplish this, the manufacturing companies should be prepared to more than double their present promotional expenditures of $225,000.

The most important merchandising efforts of the Association today are in the fields of milk, beer and glass packed fruits and vegetables. The first two named are somewhat defensive in character; the third is definitely an attempt to develop a new market for glass containers.

An interesting campaign was conducted through the Independent Grocers' Alliance of America to find out just what would happen if glass-packed foods were promoted and properly displayed in some 6,000 member stores directly to the ultimate consumer. As the annual G. C. A. meeting took place just at the half-way mark of this drive, a progress report was presented. J. Sidney Johnson, I. G. A. merchandising director, Scott Faron, G. C. A. advertising manager, and Arthur E. McElfresh of the advertising firm of Pedlar & Ryan, Inc., stated



Total industry shipments compared with productive capacity, by months.



Glass container general line shipments compared with consumer goods index.

that the drive to date was an outstanding success. The list campaign had made both retailer and wholesaler enthusiastic about glass-packed foods. This type of merchandise was found to be a profitable grocery store item, and if the merchant could be given a program, the tools to work with, and an incentive to sell, the future of glass-packed products could be painted in the brightest of colors.

E. G. Ackerman, assistant business manager of G. C. A., gave a comprehensive report of Association activities the past year, showing the tremendous volume of work they handled and the many fields of activities covered. Among the activities described by Mr. Ackerman were those in connection with legislation and reguations, the Temporary National Economic Committee, tariff regulations, patent registrations in Cuba, traffic problems and costs and statistics, as well as in connection with labor relations. Dr. Ghering also reported in some detail on the progress of technical research on testing procedure and bottle breakage. He is conducting this work at the Preston Laboratories at Butler, Pa., under the direction of Frank W. Preston. A section of Mr. Ackerman's report was also devoted to the Association's activities in connection with the establishment of glass specifications for whiskey bottles and gin bottles.

Officers elected for the coming year were: W. H. McClure, Hazel-Atlas Glass Co., president; H. C. Mandeville, Thatcher Manufacturing Co., first vice-president; C. D. King, Anchor-Hocking Glass Corporation, second vice-president; Victor L. Hall, secretary-treasurer. The resignation of George S. Bacon, Whitall-Tatum Division of the Armstrong Cork Company, from the Board of Directors was accepted with regret, and F. H. May of that same organization was elected to fill his unexpired term. Other directors with terms expiring were re-elected to office, and Clarence Avery of the Chattanooga Glass Company was elected to the Board as a new member.

• The glass-blowing show in the rotunda of the Glass Center at the New York World's Fair has attracted so much attention that two additional tiers for standees have been constructed, giving an audience capacity of 1,500 per performance.

MEETING IS DEVOTED TO STAINED GLASS

The May meeting of the New York Society of Ceramic Arts, held at the Metropolitan Museum of Art on Friday, the twenty-sixth, was devoted to a discussion of Stained Glass. Orin E. Skinner of Boston, Secretary to Charles J. Connick and editor of *Stained Glass*, the publication of the Stained Glass Association of America, was the principal speaker. He was introduced by Mr. Lawrence E. Barringer, President of the Society. Mr. Skinner, who is a Master Craftsman in the Boston Society of Arts and Crafts, presented a clear and interesting outline of the history and practice of the ancient craft from its beginnings in the eleventh and twelfth centuries to the present day.

He touched on the discovery and practices of glass making and its earliest applications to decorative pattern in windows. He also told of some of the fascinating problems in refraction and halation which confront the designer in this brilliant medium of color and light, and traced the development of the craft through the middle ages, the vicissitudes of the renaissance and its recovery during modern times.

His lecture was well illustrated with colored lantern slides from the remarkable collection which Charles J. Connick has assembled over a period o fmany years. A series of pictures outlined the process of making a stained glass window from its first conception in the small scale color sketch through the cartooning, the cutting, the painting, firing and glazing, to the complete fabric assembled in the studio. Other slides presented amazingly true impressions of ancient masterpieces in the windows of the famous Cathedrals of Europe.

Mr. Skinner also described the intriguing aspects of ever-changing light on the appearance of windows. He emphasized the disastrous effects of surface light and the importance of seeing windows at their best.

Representative New York craftsmen in stained glass were present and contributed to the discussion that followed. Mr. Otto Heinigke and Mr. J. Gordon Guthrie, both distinguished in the craft, spoke briefly, and a tour of inspection of the Museum's excellent collection of stained glass followed.

After luncheon in the Museum restaurant, the entire party embarked upon a trip to view celebrated contemporary stained glass in neighboring houses of Worship.

Temple Emanu-El on Fifth Avenue at 65th Street was first visited, to see the windows by Oliver Smith, G. Owen Bonawit, Montague Castle, Powell, and the Beth-El Chapel windows by Nicola D'Ascenzo.

At St. Vincent Ferrer's, Lexington Avenue at 66th Street, the party saw the great new west window by Charles J. Connick being installed; and viewed his other windows in the chancel, nave clerestory, baptistery and chapels. A side chancel window is designed by Connick and made by craftsmen of the Tower of Glass, Dublin. Aisle windows are by Alexander Locke, and the two delightful little narthex windows were designed by Guthrie and developed in the studio of the late Henry Wynd Young.

At the Church of the Heavenly Rest, Fifth Avenue at 90th Street, the party saw the new window over the entrance, recently completed by Powell of London, and the chancel Rose by Guthrie. His windows in the adjoining Chapel of the Beloved Disciple were also admired.

The trip ended at the Cathedral of Saint John the Divine, Amsterdam Avenue at 110th Street, with the viewing of celebrated windows by Charles J. Connick, Wilbur H. Burnham, Reynolds, Francis and Rohnstock, Ernest Lakeman and Nicola D'Ascenzo. Connick's great western Rose was radiant in the full glory of the late afternoon sun.

Of the apsidal chapels, only the one dedicated to Saint James was accessible. Here were seen the windows by Young and Lakeman and the memorial to the distinguished craftsman in stained glass Henry Wynd Young, by Metcalf and Norris.

Unfortunately, time did not permit the continuance of the tour to the Riverside Church, Riverside Drive at 122nd Street, or The Cloisters at Fort Tryon Park. Many notable windows had to be omitted, including those in Saint James Church, Madison at 71st Street: Saint Michael's, 225 West 99th; Saint Bartholomew's. Park Avenue at 51st; Saint Thomas', Fifth Avenue at 64th; and Saint Peter's on Barclay Street.

For those visitors to New York who want to see representative examples of the City's vast treasure in stained glass, an excellent list can be found in Charles J. Connick's, *Adventures in Light and Color*, published by Random House. A condensed list was published in the *Liturgical Arts* magazine, second quarter, 1937.

URBANA CONFERENCE

In view of the numerous inquiries from friends regarding the next Glass Conference to be held at the University of Illinois in Urbana, announcement is made that plans are under consideration for a conference to be held during the fall. No conference was held this spring because of the fact that the annual meeting of the American Ceramic Society was held in Chicago, Illinois, in April and, therefore, it seemed unwise to schedule a Glass Conference in Urbana, Illinois, during May.

ILLINI CERAMIST PUBLISHED

The 1939 edition of "The Illini Ceramist," which is prepared by students of the Department of Ceramic Engineering at the University of Illinois, has just been published. This is the third annual publication produced by this group and gives an excellent picture of the activities in one of the most prominent ceramic colleges. Photographs of the graduating students together with their activities and the type of work which they have specialized in are presented. Also the equipment—both man-power and mechanical—of this department, headed by Professor C. W. Parmalee, together with the qualifications of each individual instructor are given.

DR. MOREY IS HONORED

Dr. George W. Morey of the Geophysical Laboratory of the Carnegie Institute in Washington was the recipient of the honorary degree of Doctor of Science at the Commencement of the New York State College of Ceramics at Alfred, N. Y., in recognition of his authorship of 79 scientific papers dealing with various aspects of ceramic science—but, more particularly, in recognition of his recently published work, "Properties of Glass." Others honored at Alfred were Ernest W. Knapp and Robert F. Sherwood, who received degrees of Ceramic Engineer.

THERMOLUX GLASS— INSULATING, TRANSLUCID, LIGHT-DIFFUSING

• *Translated from an article in "Glaces et Verres," Oct.-Nov.* 1938, *by Elsie A. Preston.*

The essential elements of the above article were derived from a lecture given to the Centre d'Information et de Documentation des Architects by M. de Tailly, engineer of Arts and Manufactures, director of the Verreries Mécaniques de Bourgogne.—THE EDITOR.

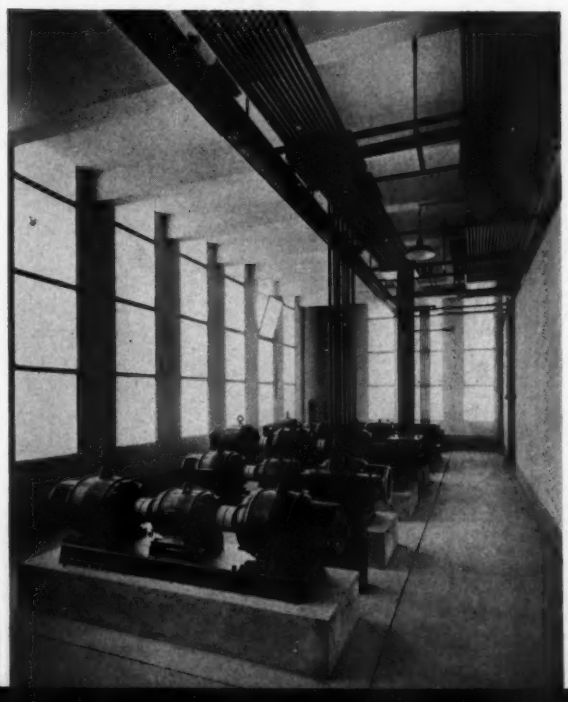
Thermolux glass consists of a felt of glass threads fixed between two sheets of glass. This felt, called "Vetroflex," is composed of glass threads of very fine diameter (2-3 hundredths of a millimeter). To this fineness are due the chief properties of the new glass.

The manufacture of glass thread, which is also called "glass silk," is rather delicate, although the principle is not new. For a long time past artisans have effected this operation by heating the end of a glass rod with a blow-pipe. As soon as the glass is sufficiently softened it is stretched by placing it on a wheel which is revolved at great speed. The thread, as it forms, is wound on to the wheel, fed by the fusion of the glass rod which the workman maintains with his blow-pipe.

Industrially, it has been necessary to make the process more regular and to provide a greater output. A mass of melted glass is maintained in a small horizontal furnace, the bottom being pierced by numerous small holes, from each of which a thread of glass is taken. The whole flock of threads is wound on to a drum which revolves underneath. To obtain the felt, the drum and the furnace are given reciprocating motions with regard to each other, so that the webs of thread cross and recross each other in proportion as they are unwound.

The thicknesses in which the felt is manufactured are 10, 15, 20, 25 and 30 tenths of a millimeter. The thickness of glass between which the felt is fixed is from 1.7 to 5.7 mm.

To define Thermolux one uses a term of four figures, of which the first two indicate in tenths of a millimeter the total thickness of the glasses, and the last two that of the felt. Thus, type 5520 corresponds to a thickness of 2 mm. packing and 5.5 mm. for the two glasses, approximately 2.7 mm. for each of them. The total thickness of Thermolux type 5520 is therefore approximately 2 mm. + 5.5 mm. = 7.5 mm.



Thermolux glass used in the power plant at Argenteuil.

It will be noticed that there exist some types of "industrial" Thermolux composed of two sheets of rolled glass, or of one sheet of rolled glass and one of reinforced glass, between which felt is inserted, of varying thickness. The definition of these types is effected in the same way, by four figures.

A few words now on the assembling of glass and felt. To effect this the edges of the glass are roughened with sand and a special weather-resistant gum injected into the latter. Up to date the only suitable gum which could be used has had an asphaltic base, and is consequently black. It is often worth while to hide it under a deep rebate or a fair-sized border.

The width to be allowed for the border is determined by the greatest dimension and the thickness of the glass. It varies from 6-20 mm.

Thermal Properties

A study of the transmission of heat through the panes has established beyond doubt that it decreases with the thickness of the glass; but if the pane is made of two glasses separated from each other by a layer of air it is found that the influence of the thickness of glass almost disappears in comparison with that of the layer of air interposed. If this layer of air is immobilized by the introduction of criss-cross fibres of small diameter the effect is increased considerably. A 3 mm. layer of glass silk is as effective as a 15 cm. layer of air.

Let us imagine a wall of 140 sq. ft., say 13′ 1″ x 10′ 8″ high x 16″ thick. (Fig. 1.) In this wall a window is made, closed by 6 mm. (¼″) plate glass. The dimensions are calculated to make the heat lost through the plate glass equal to that lost through the masonry. This window, closed by plate glass, will have an area of 25 sq. ft., say 6′ 10″ high x 3′ 7″ wide.

If Thermolux is used, so as to have the same total loss of heat through the wall and through the window, we can allow an area 52 sq. ft., 6′ 10″ high x 7′ 3″ wide. The opaque area of the wall which was in the first case 115 sq. ft., is no more than 88 sq. ft.

To obtain a specially efficient thermal insulation, a ¼″ plate glass and a Thermolux are superimposed in a double window; one obtains then, with the same total loss of heat a window surface of 90¼ sq. ft., say 13′ 1″ wide x 6′ 10″ high, i.e. the window extends the whole width of the wall.

Thus Thermolux is substituted for the full wall, and the construction obtained responds to the demands of modern aesthetics, without which living conditions are uncomfortable.

Very appreciable economy in the heating of glazed workshops has been effected, when it has been possible

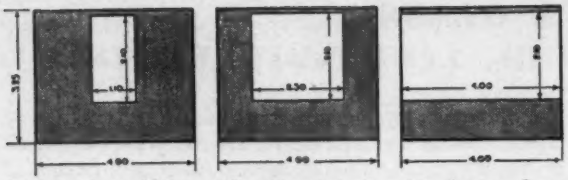


Fig. 1. From left to right: Opening glazed in 6-mm. glass; opening glazed in 8-mm. Thermolux; double glazing, glass and Thermolux. Glazed openings in a wall of 0.40-m. The heat loss is the same in the three instances.

to substitute Thermolux for the simple glazing which lighted them.

To be more precise, let us imagine that, in a workshop in the region of Paris 100 sq. m. of cathedral glass are replaced by 100 m² of Thermolux 6025. The coefficient of conductivity of the cathedral glass, allowing for the influence of the wind is 5.52 and that of Thermolux 3.8. For heating to 18°C. (64.4°F.) during three months in winter and 1½ months in spring and autumn, the saving will be 9,000,000 calories, which represents, for coke burned in an apparatus at 70 per cent efficiency, about 650 francs p.a.

Attention must be called also to a particularly interesting industrial application. It has to do with windows of dyers' workshops and certain spinning mills, in which it is necessary to work in a humid atmosphere. When the outside temperature drops, great difficulty is caused by the condensation of water on the glass roof, which falls finally in drops of water on to the products in course of manufacture, and sometimes causes considerable damage. It has been found that with Thermolux there is a gain of about 10° before arriving at the dew point, with an atmosphere of 50 per cent saturation.

Diffusion of Light through Thermolux

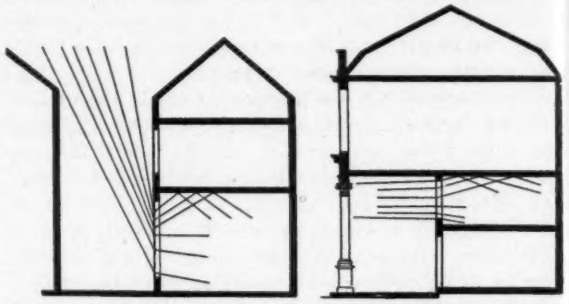
When the light reaches the numerous little cylinders which the threads form it is refracted and reflected in every direction, and leaves the pane perfectly diffused. However, the fibres of the felt are not oriented indiscriminately, but have a predominating direction. If their orientation approaches the horizontal the light is but slightly diffused in the direction of the axis of the cylinders, but strongly in the perpendicular direction. It is not therefore a matter of indifference to place a Thermolux glass destined for a particular purpose in a random orientation.

If it is required to light a workshop which only receives light obliquely, coming from above, the glass thread and fibres must be carefully placed so that their orientation approaches the horizontal (Fig. 2a). A part of the light will be sent back to the ceiling instead of being directed towards the floor, where it would be absorbed and consequently useless. The ceiling, which is generally white, will send it back, on the contrary, on to horizontal surfaces of tables or apparatus, where it is required. The application is the same for a mezzanine receiving daylight under arcades (Fig. 2b).

On the other hand, in a long passage, lit at only one point by a window the length of its side wall, the threads will have to be oriented vertically, in order to send the light towards the ends of the corridor.

In this transmission a part of the light is absorbed by the glass silk. However, the diffusion is such that the contrasts between shadows and patches of light disappear, and the eye, having the faculty of keeping the iris wider open, receives on the whole more light, resulting in an impression of greater illumination, and with less fatigue.

Applications to large buildings have been absolutely conclusive in this respect. One engineering enterprise occupies a large workshop with a glass roof. Thermolux glass was substituted, over a length of about 650 ft., for the wire glass which was used previously. After preliminary tests it was found that the ease of working and the greater output justified the expense. In the change over, only half the length had been glazed with Thermolux, the other half still having wire glass. In this latter part the sun which penetrated the roof made hard shadows, a nuisance both to circulation and work. The workmen were obliged to turn their backs to the light, so as not to have it in their eyes, after having spread out their tools and equipment all round. The appearance of the workshop was consequently not attractive. In the second part, on the contrary, glazed with Thermolux, there was greater comfort in the circulation, and it was immediately noticeable that there was perfect order.



Left to right: Fig. 2a. Elevation of a building lit from a court. Fig. 2b. Elevation of a mezzanine receiving light through the arcades.

Left to right: Fig. 3a. Roof glass (ridge, north-south). Fig. 3b. Sawtooth roof (ridge, east-west).

A scene in a plant at Chalon-sur-Saone, showing the use of Thermolux.

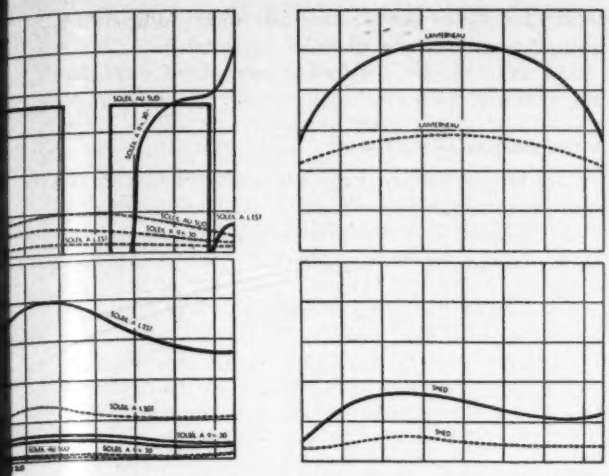


Fig. 4. Left: Lighting curves in the interior of buildings lit by roof glass (upper graph) or sawtooth roof (lower graph), glazed with ordinary glass (heavy line) or Thermolux (dotted line). Sun exposed. Fig. 5. Right: Curves obtained under same conditions as Fig. 4, but with sky generally cloudy. Ordinary glass: heavy line. Thermolux: dotted line.

An example of the use of Thermolux in Lyons.

Another scene in the same building in Lyons showing the use of Thermolux.

The English have made photometric measurements on clay models, representing workshops lit by roof-glass and by a window in a sawtooth roof (Figs. 3a and 3b). They have traced curves of light into the interior in both cases at eye level.

1. Sun's rays, the sun being represented by a strong lamp (Fig. 4).
2. Diffused light from a sunless sky (Fig. 5).

These curves indicate very clearly a more uniform distribution of light and the dissolving of the tiring places in direct sunlight. Morning and evening, in the case of the glass roof with Thermolux surfaces facing East and West, the natural light is very appreciably prolonged, and there is a corresponding economy in artificial light. The horizontal light which comes directly through the glass is usefully diffused downwards by the Thermolux.

Thermolux therefore frees the architect from the constraints to which he has been subject in planning industrial buildings, by reason of the orientation which was required for window lights.

In sawtooth-roof skylights facing North, Thermolux makes it possible to substitute glass roofs oriented in any way, and in particular facing East and West, the roof ridge running North and South.

Reflection of Light by Thermolux

The capacity for reflection on the assembled sheet of glass carries another special property. While the light from outside a workshop is greater than the light inside, the window lights the people within. If, at the close of day, the interior is lit by artificial light, Thermolux has a brightly lit appearance from inside, and from outside it is not possible to see what is happening within. The usual operation of window shades therefore becomes unnecessary.

Other diffusing glasses exist, in particular prismatic glasses, which solve the problem of lighting the depths of a court. Thermolux has a great advantage over these in having smooth surfaces which keep clean and do not collect dust. Its luminosity remains constant, and it is needed everywhere where hygiene and cleanliness are necessary.

Deadening of Noise

Thermolux is a very efficient acoustic insulator. The felt of glass silk deadens the vibrations received by one surface before transmitting them to the other surface.

According to a communication from M. Polivka to the Society of Civil Engineers,* if a pane of homogeneous glass 2 mm. thick has an insulating capacity of 22 phons, that of 10 mm. thickness would have an insulating power of 27 phons. The same panes mounted in a double window would have a capacity of 34-42 phons.

A simple Thermolux with the total thickness of 5 mm. has an insulating power of 42 phons, say the same as a double window, and with a thickness of 10 mm.—45 phons. A double window of 5.5 mm. Thermolux has an insulating power of 56 phons, and the same in 10 mm. Thermolux—58 phons.

Safety and Decoration

Thermolux glass gives guarantees of solidity which are very superior to those provided by sheet glass. It is

*Presumably of France.

Another example of the use of Thermolux.

not, however, a safety glass resisting the impact of heavy masses. In order to approximate as nearly as possible to the conditions in which skylights are used in practice, experiments were made to reproduce the impact of hailstones.

A series of boxwood billiard balls was made, with a density equal to 0.985, approximating very closely to that of the ice which forms hailstones (say 0.92), and having increasing diameters. For the purpose of the test they were dropped from a height of 62 ft. on to samples of glass 2′ 0″ x 1′ 6″.

The results shows that the resistance of Thermolux is very nearly double that of an ordinary pane, and it is remarkable that even when the lower sheet of glass was broken through, very little glass fell; the glasses were still held together by the silk between them and by the gum of the border.

Thermolux is required chiefly for industrial purposes. However, colored glass is made in five different shades, and there is no reason why this range should not be extended in the future.

The translucid panels obtained with colored glass silk keep the heat-absorbing and light-diffusing properties of white Thermolux. For partition glazing they seem more decorative and better adapted to the modern conception of interiors than the various glasses used up to date. Their cleanliness and the ease with which they are kept in good condition constitute appreciable advantages in this respect. Colored Thermolux can even be used in decoration, in the form of cornices in offices or clinics, for example. Another use of Thermolux is for painting letters on the inside surface of glass; they are worked out in a particularly neat fashion on the glass silk, lying deep out of reach of frosts and changes of temperature. Let us add finally that Thermolux stained glass windows have been developed in Italy. The varied tints of the glass threads are combined to compose decorative motifs. Some curious and novel effects are obtained.

Fixing in Position

The fixing of Thermolux must be carried out with special care, and it must never be forgotten that the orientation of the glass silk fibres plays a very important role in the lighting effect obtained. Moreover, although it may not be absolutely impossible to recut a manufactured sheet, it is a delicate operation, long and risky. It is necessary, therefore, to take the measurements carefully, providing for the customary tricks of ordinary panes.

It will always be helpful to send a sketch with an order, especially if it is a question of several glasses together.

If the glasses have to be cut in special forms a pattern is required. This would be best cut in sulphuretted paper,* the dimensions of which do not vary with humidity. It is not unusual to see papers suffer an expansion of the order of 1 cm. per metre, according to humidity of the surroundings into which they are brought. For greater security the chief dimensions can be reported on the pattern.

As regards the carrying out of the installation, account must be taken of the fact that the bituminous mastic of the sealing of the panes could be decomposed by the linseed oil of ordinary glaziers' mastics. Thermolux is fixed with one of the special mastics containing no linseed oil, which are now available in the trade.

The mastic receives itself a last layer of red lead before the final coat.

Application

Here are the principal cases in which Thermolux has been employed in France and abroad.

1. Factories, designers' offices, laboratories, engineering workshops, weaving and spinning mills, inspection services and stores. Thermolux possesses all the necessary properties for giving illumination by zenithal light coming from the East, South or West. It assures a perfect diffusion over the area of work, while at the same time insulating against loss of heat from the interior to the exterior and against the direct impact of the sun;

2. Warehouses, exhibition rooms, shops. To the above advantages it adds that of being attractive to the eye and of transmitting an abundance of light which is not tiring. It is needed in certain shops which sell perishable goods;

3. Hospitals, schools, hotels. It permits of maintaining rooms easily at an even temperature in summer and winter.

4. Studios of art and photography, lecture halls, museums, art galleries. It constitutes an efficient screen against the sun, and permits continuous work or examination without fatiguing the eyes, without having recourse to shades during the periods when the windows are exposed to the sun, and it keeps down blinding reflections.

*We are advised by the Secretary of the American Chemical Society that there is no paper which does not shrink with humidity.

CANADIAN INTEREST IN AMERICAN GLASS STIMULATED

Unsettled conditions in important foreign glass and pottery-producing countries have stimulated the interest of Canadian buyers in American wares, according to a report from the American Consulate General at Toronto made public by the Department of Commerce. Formerly, certain foreign lines were produced solely to appeal to the tastes of the North American markets. Decreased purchases of these wares by the United States is expected to result in their withdrawal from production. The trade doubts that these items will be made for the smaller Canadian market, according to the report.

Several Canadian buyers made their first purchases of American pottery and glassware during recent weeks. In this connection, it was pointed out that in the past higher prices were considered an obstacle to the sale of these wares. It is also reported that replacement of former hand-decorated Czechoslovak glassware seems to be a very difficult matter because of the individuality which was possible in the cottage industries of that country.

The Department of Commerce said that in view of this trend it might be well for American pottery and glass manufacturers to study the possibilities of the Canadian market. The Specialties Division and other divisions of the Bureau of Foreign and Domestic Commerce have offered to cooperate in this matter. During the 12-month period ending March, 1939, total imports of these wares into Canada approximated $4,000,000, according to the Department of Commerce.

"SHRUNK" GLASS RESISTS EXTREME HEAT AND COLD

• *It should be noted that the following account of one of the most recent developments in glass has been taken from a general publicity release from the Corning Glass Works and therefore tends to the "popular" rather than technical in its description. However, the essential facts are contained in the following description.—The Editor.*

An entirely new method of glass manufacture yielding products which can be heated to cherry red heat and then plunged into ice water without breaking has been developed in the research laboratories of Corning Glass Works, according to Amory Houghton, President. The Corning management made clear, however, that while the Research Department had completed its exploration into the unknown and had established its findings beyond doubt, it will be two years or more before the products can be offered to the public.

The most interesting point about this new and revolutionary process is that articles made by it shrink to less than two-thirds their original volume yet retain their identity and suffer no distortion of form. This means a linear shrinkage of 13 per cent. For instance, if you want to end up with a nine-inch dish you first make one ten and a half inches in diameter.

The new Corning process consists of a series of contrasting operations and there are several alternative variations at the end which give an amazing variety of results. In simplest terms, what happens in the main process is this. A normal glass object such as a plate or beaker is made by usual melting and molding operations but with a special glass formula to start with. Then through a series of treatments involving final leaching with dilute nitric acid part of the structure of the glass is removed leaving a skeleton, so to speak. Under further heat treatment the glass shrinks down to a volume which is 35 per cent smaller than its original size! As a matter of fact, during the acid treatment 36 per cent of the body of the glass has been removed. The surface feels rough to the touch but does not feel porous. Actually at this stage it is filled with submicroscopic capillaries or air spaces. On final heat treatment the glass body shrinks to a transparent, homogeneous state in which it is practically 96 per cent pure silica. In this completed state the glass can be heated to a bright cherry red color, and then dipped into a vat of ice water with no injury whatsoever.

The outstanding significance of the new Corning low-expansion glass is that it will offer in an economical price range a material similar to fused quartz. Incidentally, it was just a hundred years ago, in 1839, when A. Gaudin, in France, showed that molten quartz could be worked like glass. A quartz crystal which is silicon dioxide, of which sand is a form, can be melted at the high temperature of the oxy-hydrogen flame and in that manner can be formed into various vessels chiefly for laboratory use. The resulting silica glass stands sudden changes from hot to cold without appreciable injury. Fused quartz, or, better, silica glass, has not been found adaptable to mass production methods of fabrication and hence its application outside of specialty fields has been curtailed. The new glass product is for practical purposes equal to fused quartz or fused silica ware, and indications are that it can be manufactured by mass production methods and at resultant low costs.

Corning Glass Works' officials were reluctant to give any emphasis to possible fields of application. However, the process has been definitely achieved from a research standpoint though it is still subject to continuous experimentation with a view to standardization and improvement. A miniature pilot plant has been operating for several months. To put the process on a full-scale basis would require at least two years, even assuming rapid designing and building, according to the chemists in charge.

Back in 1915 Dr. E. C. Sullivan, Vice Chairman of the Board and now Research Director, and W. C. Taylor, now Chief Chemist of Corning Glass Works, took the significant step of inventing a range of glasses known technically under the classification of borosilicate glasses. These glasses which have received wide public acceptance under the Pyrex trade-mark are highly resistant to thermal shock.

The patent covering the new process was taken out by Mr. H. P. Hood and Dr. Martin E. Nordberg and was assigned to Corning Glass Works. Hood and Nordberg are chemists under Mr. Taylor in the research staff.

PHYSICAL PROPERTIES COMPARED

	New Glass	*Previous Low Expansion Glass*	*Fused Quartz*
Softening Point	1442°C.	819°C.	1667°C.
Annealing Point	931	553	1140
Strain Point	857	510	1070
Max. temperature for use (for considerable period)	900 to 1000°C.	500 to 600°C.	1100
Density (Sp.G.)	2.18	2.23	2.21
Coefficient of Linear Expansion	7.8 to 8 x 10^{-7}	32 to 33 x 10^{-7}	5.5 to 5.85 x 10^{-7}

Technical description of the most important steps in the new Corning glass-making method is somewhat as follows: The starting object, say a dish, flask, beaker or tube, is produced from certain original types of borosilicate glasses which are somewhat unstable. By means of a heat treatment these glasses are separated into two phases, one being high in silica and highly stable, the other containing substantially no silica and being very soluble in the common acids. This second phase is then extracted by leaching in an acid bath for some period of time, which leaves a skeleton-like structure of high silica glass. This is then fired at a vitrifying temperature to condense this structure, which is porous, into a clear, solid mass. It is during this final heating that the shrinkage occurs.

CURRENT PRICES OF GLASS-MAKING MATERIALS

FURNISHED BY PRODUCERS, MANUFACTURERS AND DEALERS

Base Materials

		Carlots	Less Carlots
Barium carbonate ($BaCO_3$), Crude, (Witherite) 90%, 99% through 200 mesh	ton	43.00	46.00
Barium sulphate, in bags	ton	19.00	24.00
Barium sulphate, glassmaker's, carlots, bulk f. o. b. shipping point	ton	15.00-16.00	18.00
Borax ($Na_2B_4O_7 10H_2O$)	lb.	....	....
Granulated	In bags, lb.	.0215	.027 -.0295
Powdered	In bags, lb.	.024	.0295-.032
Boric acid (H_3BO_3) granulated	In bags, lb.	.048	.054 -.0565
Calcium phosphate ($Ca_3(PO_4)_2$)	lb.	.07	.07½
Cryolite ($Na_3Al F_6$) Natural Greenland (Kryolith)	lb.	.0865	.0925
Synthetic (Artificial)	lb.	.0825	.0875
Feldspar—			
20 mesh	ton	11.00-13.25	
40 mesh	ton	11.50-13.75	
Granular	ton	11.75-14.00	
Semi-granular	ton	11.00-13.25	
L. C. L., (Min. 2 tons) $3.00 per ton additional plus charge for bags			
Fluorspar (CaF_2) domestic, ground, 96-98% (max SiO_2, 2½%)			
Bulk, carloads, f. o. b. mines	ton	29.00	....
In bags	ton	30.60	40.00-42.00
Kryolith (see Cryolite)			
Lead Oxide (Pb_3O_4) (red lead) (N. Y.)	lb.	.0725	....
In 5 Ton lots	lb.	....	.0775
Less than 5 Tons	lb.	....	.0825
Lime—			
Hydrated ($Ca(OH)_2$) (in paper sacks)	ton	8.50	8.50
Burnt (CaO) ground, in bulk	ton	7.00	....
Burnt, ground, in paper sacks	ton	9.00	9.00
Burnt, ground, in 180 lb. drums	Per drum	1.60	1.70
Kiln Dried ($CaCO_3$) 10x30 mesh	ton	1.75	....
Kiln Dried ($CaCO_3$) 16x120 mesh	ton	1.75	....
Nepheline Syenite, f. o. b. shipping point	ton	12.00-14.00	....
Potassium carbonate—			
Calcined (K_2CO_3) 96-98%	lb.	.065	.0675
Hydrated 80 85%	lb.	.055	.0575
Salt cake, glassmakers (Na_2SO_4)	ton	15.00	25.00
Soda ash (Na_2CO_3) dense, 58%—			
Bulk	Flat Per 100 lb.	.95	....
In barrels	Per 100 lb.	1.35	....
In bags	Per 100 lb.	1.10	....
Sodium nitrate ($NaNO_3$)—			
Refined (gran.) in bbls	Per 100 lb.	....	2.50-2.90
95% and 97%			
Bulk	Per 100 lb.	1.35	....
200 lb. bags		1.415	1.44
100 lb. bags		1.45	1.475

Special Materials

		Carlots	Less Carlots
Aluminum hydrate ($Al(OH)_3$)	lb.	.029	.03½
Aluminum oxide (Al_2O_3)	lb.	.07	.09
Antimony oxide (Sb_2O_3)	lb.	.10½	.11¼
Arsenic trioxide (As_2O_3) (dense white) 99%	lb.	.03	.03½
Barium nitrate ($Ba(NO_3)_2$)	lb.	....	.07¾
Pyrophyllite, (20% Al_2O_3)	ton	9.00	12.00
Sodium fluosilicate (Na_2SiF_6)	lb.	.035-.04	.04¼-.05
Tin Oxide (SnO_2) in bbls	lb.	....	.52
Titanium Oxide (ceramic grade)			
In bags	lb.	.12¼	.12½-.13
In barrels	lb.	.12½	.12¾-.13¼
Zinc Oxide (ZnO)			
American process, Bags	lb.	.06¼	.06½
White Seal, 150 lb. bbls	lb.	.08¼	.09
Green Seal bags	lb.	.08	.08¼
Domestic White Seal bags	lb.	.08¼	.08¼
Red Seal, bags	lb.	.07½	.07¾
Zircon			
Refined Granular (Milled .01-.02c higher)		.06½	.07-.08
Commercial, Gran. (Milled .01¼-.01½ higher)		.0275	.0325

Coloring Materials

		Carlots	Less Carlots
Barium selenite ($BaSeO_3$)	lb.	....	1.40-1.60
(Commercial. 25% Selenium)	lb.	....	.85
Cadmium sulphide (CdS)	lb.	....	70 .75
Chromite (99% through 200 mesh)	ton	35.50	40.00
Chromite ore (air floated)	ton	55.00	58.00-73.00
Cerium hydrate—			
100 lb. drums and 600 lb. barrels	lb.	....	.60
Chrome Oxide Green. 400 lb. bbls.	lb.	....	.22-.26
Cobalt oxide (Co_2O_3)			
In bbls	350 lbs. or more, lb.	....	1.67
	Less than 350 lbs., lb.	....	1.77
Copper oxide—			
Red (Cu_2O)	lb.	....	.165
Black (CuO)	lb.	....	.16-.17
Black prepared	lb.	....	.22
Iron Oxide—			
Red (Fe_2O_3)	lb.	....	.0425-.09
Black (Fe_3O_4)	lb.	.04½	.09
Iron Chromate	lb.	....	.035-.05
Lead Chromate ($PbCrO_4$) in bbls	lb.	....	.145
Manganese, Black Oxide			
In Paper bags	ton	47.50	50.50-54.50
In Burlap bags	ton	49.25	51.75-56.75
In Casks	ton	51.50	54.00 59.00
Neodymium oxalate, 50 lb. drums	lb.	....	3.50
Nickel oxide (Ni_2O_3), black	lb.	....	.35-.40
Nickel monoxide (NiO), green	lb.	....	.35-.37
Potassium bichromate ($K_2Cr_2O_7$)—			
Crystals	lb.	.08¾	.09-.09¼
Powdered	lb.	....	.09¼-.09¾
Potassium Chromate (K_2CrO_4) 100 lb. kegs	lb.	....	.27
Powder blue	lb.	....	.17-.2125
Rare earth hydrate—			
100 lb. drums	lb.	....	.35
325 lb. barrels	lb.	....	.30
Selenium (Se) In 100 lb. lots	lb.	....	1.75
In lesser quantities	lb.	....	1.85
Sodium bichromate ($Na_2Cr_2O_7$)	lb.	.06¾	.07-.07¼
Sodium chromate (Na_2CrO_4) Anhydrous	lb.	.08¼	.08¾-.08¾
Sodium selenite (Na_2SeO_3)	lb.	....	1.50-1.65.
Sodium uranate (Na_2UO_4) Orange	lb.	....	1.75-1.80
Yellow	lb.	....	1.75-1.80
Sulphur (S)—			
Flowers, in bbls	Per 100 lb.	3.35	3.70-4.10
Flowers, in bags	Per 100 lb.	3.00	3.35-3.75
Flour, heavy, in 250 lb. bbls	Per 100 lb.	2.90	3.25-3.65
Uranium oxide (UO_2) (black, 96% U_3O_8) 100 lb. lots. Black	lb.	....	2.65-2.75
Yellow orange	lb.	....	1.75-1.80

Polishing Materials

		Carlots	Less Carlots
Emery, Turkish	lb.	.063	.07
Pumice Stone,			
American Ground Italian FFF, FF, F	lb.	....	.03
0, 0½, ½, 1.	lb.	....	.03¼
Putty Powder	lb.	....	.38-.42
Rotten Stone, (Domestic)	lb.	....	.02
Rouge, Red	lb.	....	.14
Black	lb.	....	.16

EQUIPMENT AND SUPPLIES

NEW FILTER RESPIRATOR

Willson Products, Inc., 346 Thorn St., Reading, Pa., have announced the development of their Type B Mechanical-Filter Respirator for protection against fumes of metals. Designated as Willson Respirator No. 770, this new product bears Bureau of Mines Approval No. 2128 "for protection against fumes of metals such as lead, mercury (except mercury vapor), manganese, magnesium, aluminum, antimony, arsenic, copper, chromium, iron, cadmium and zinc resulting from sublimation or the condensation of their vapor, or from chemical reactions between their vapors and gases." Of special importance is the protection afforded against the

inhalation of lead fumes generated by heating and volatilizing lead, such as the fumes generated in lead burning and soldering, smelting, type founding, and fusing lead glaze and enamel.

The rubber face mask of the respirator fits snugly under the chin and an air-tight contact is obtained with but slight tension on the adjustable double elastic headband. Exhalation of used air through a properly placed exhaust valve is aided by twin inhalation valves in the mask interior. The filters may be readily cleaned. All parts are said to be economically replaceable.

HEADS REFRACTORIES GROUP

At its annual meeting in Pittsburgh, June 1, W. J. Westphalen, president and general manager of Laclede-Christy Clay Products Co., was re-elected president of the American Refractories Institute. Mr. Westphalen, who has been associated with the Laclede organization for more than 30 years, has recently been made president of that company.

● The Claud S. Gordon Co., industrial engineers, Cleveland, Ohio, has announced the appointment of N. A. Feldman as office manager and purchasing agent.

● The International Nickel Co., Inc., 67 Wall St., New York, has issued a handy, pocket-size, hardness conversion table for nickel alloy steels. Included are S.A.E. specifications for nickel alloy steels.

GLASS BLOWING

The Laboratory and Pharmaceutical Division of the Corning Glass Works has recently published a manual, "Laboratory Glass Blowing with Pyrex Brand Glass." It contains information on the working characteristics of Pyrex, an explanation of fundamental glass blowing operations and recommendations of suitable tools and equipment.

CATALOG & BULLETIN SERVICE

Current catalogs and manufacturers' service bulletins reviewed in this department may be obtained by writing to THE GLASS INDUSTRY.

Toledo Engineering Co., 958 Wall St., Toledo, Ohio, have published a new bulletin, giving complete information on the latest developments in luminous-flame firing for glass melting together with a detailed description of the TECO system for luminous flame control and utilization.

Laclede-Christy Clay Products Co., St. Louis, Missouri, have issued an attractive folder describing their new "Furnascote" refractory maintenance mixture. In addition to describing the properties of this new material for furnace walls, data is given on how to mix, apply and figure requirements.

Ransome Concrete Machinery Co., Dunellen, N. J., have issued a letter-size mailing piece describing their glass batch mixers and stressing the fact that they are dust-proof. They invite further inquiries.

Pangborn Corporation, Hagerstown, Md., have issued their Bulletin No. 905, describing their Precipitron for the industrial cleaning of air and gas. Fully diagrammed and attractively illustrated, this publication gives many details of the operation of the equipment as well as a list of typical installations.

Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa. Catalog No. N-01-163, entitled "Metermax Combustion Control for Boiler Furnaces," is an illustrated 32-page booklet covering application of control to furnaces of every major type.

Matthews Conveyor Co., Elwood City, Pa. Conveyors Handbook, Catalog No. HB39, is an illustrated, pocket-size book of 384 pages which includes data on all the various types and sizes of Matthews equipment. The book is offered to engineers and plant operating men without obligation.

A. P. Green Fire Brick Co., Mexico, Mo. New 8-page, illustrated booklet describes various types of firebrick, including data on composition, testing and application.

Eclipse Air Brush Co., Inc., 390 Park Ave., Newark, N. J. Four-page folder catalogs complete line of air-motored agitators, both direct and gear driven, for use with paint spraying equipment.

Chicago Eye Shield Co., 2300 Warren Blvd., Chicago, Ill. New 48-page book entitled "Industrial Head and Eye Protection" lists and describes complete line of goggles, respirators, spectacles, masks, welding helmets and other safety devices. Illustrated.

Jeffrey Manufacturing Co., Columbus, Ohio. General Catalog No. 87 illustrates and describes complete line of power drives and material handling equipment. To obtain a copy of the 960-page book request should be sent to the manufacturer on company letterhead.

The American Brass Co., Waterbury, Conn. (American Metal Hose Branch), has published a 24-page catalog with 75 up-to-date pictures. It contains complete discussions on the proper use of the product for conveying steam, liquids, gases; controlling vibration, connecting misaligned and moving parts.

NEW COMBUSTION REGULATOR

The Minneapolis-Honeywell Regulator Co., Minneapolis, Minn., reports the development of their new Type VO80A combustion regulator, which is designed to hold the steam pressure in a gas fired boiler within close limits and to control the air supply to the burner in conjunction with the gas, resulting in high combustion efficiencies.

High pressure safety is one of the functions of the regulator; the convenient terminal panel, however, is arranged for easy incorporation of additional safety devices such as a low water cut-off, a Pilotstat or a flame safeguard relay. Any interruption of the electrical safety circuit by one of the above devices will cause complete safety shutdown of the gas valve regardless of the demand on the regulator due to low steam pressure.

Installation is reported to be extremely simple as the entire control is mounted on the gas valve bonnet at a single point. A ¼ inch steam supply and exhaust line and connection to the electric service complete the installation.

NEW BOOK ON ALLOY CAST IRONS

• *Alloy Cast Irons*, a Project of the Gray Iron Division of the American Foundrymen's Association. Semi-flexible imitation leather, 270 pages, 6 x 9 inches, 111 charts and illustrations, 73 tables, published by the American Foundrymen's Association, 222 W. Adams St., Chicago, Ill. Price $3.00.

"Alloy Cast Irons" covers the effect of 18 different elements on the various properties of gray, white and chilled cast irons. Information is given on the effect of aluminum, bismuth, carbon, chromium, cobalt, copper, magnesium, manganese, molybdenum, nickel, phosphorus, silicon, sodium, sulphur, titanium, tungsten, vanadium and zircomium on such properties as tensile, transverse, shear, torsional and impact strengths, hardness, deflection, machinability, wear resistance, heat resistance, corrosion resistance, mass and section, electrical properties, thermal properties, chill, etc.

"Alloy Cast Irons" also discusses the forms in which alloying elements are available commercially and the different types that are added to various melting units. General foundry practice used in the manufacture of alloy cast irons, covering such subjects as melting, molding sands, heat treatment, shakeout practice, cleaning and finishing, etc., also is covered.

Of special interest should be the chapter devoted to composition, mechanical properties, uses and service data on many types of alloy cast irons in commercial applications. For those desiring still more complete information on the subjects covered, a 25-page bilbliography is available. The 14-page cross index at the rear of the book makes the desired information easily found.

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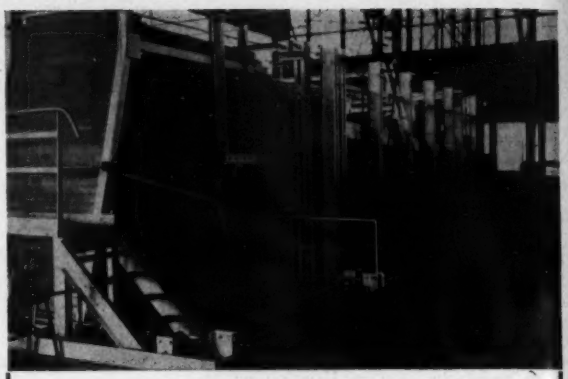

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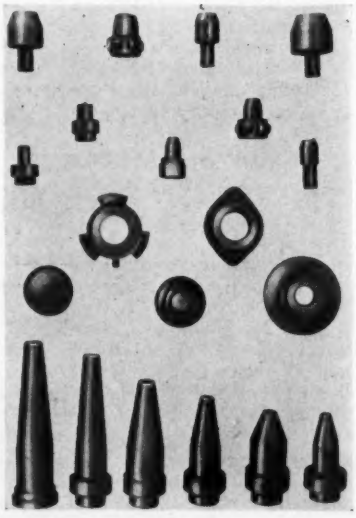

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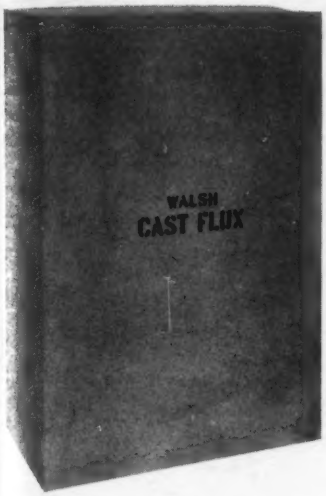

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